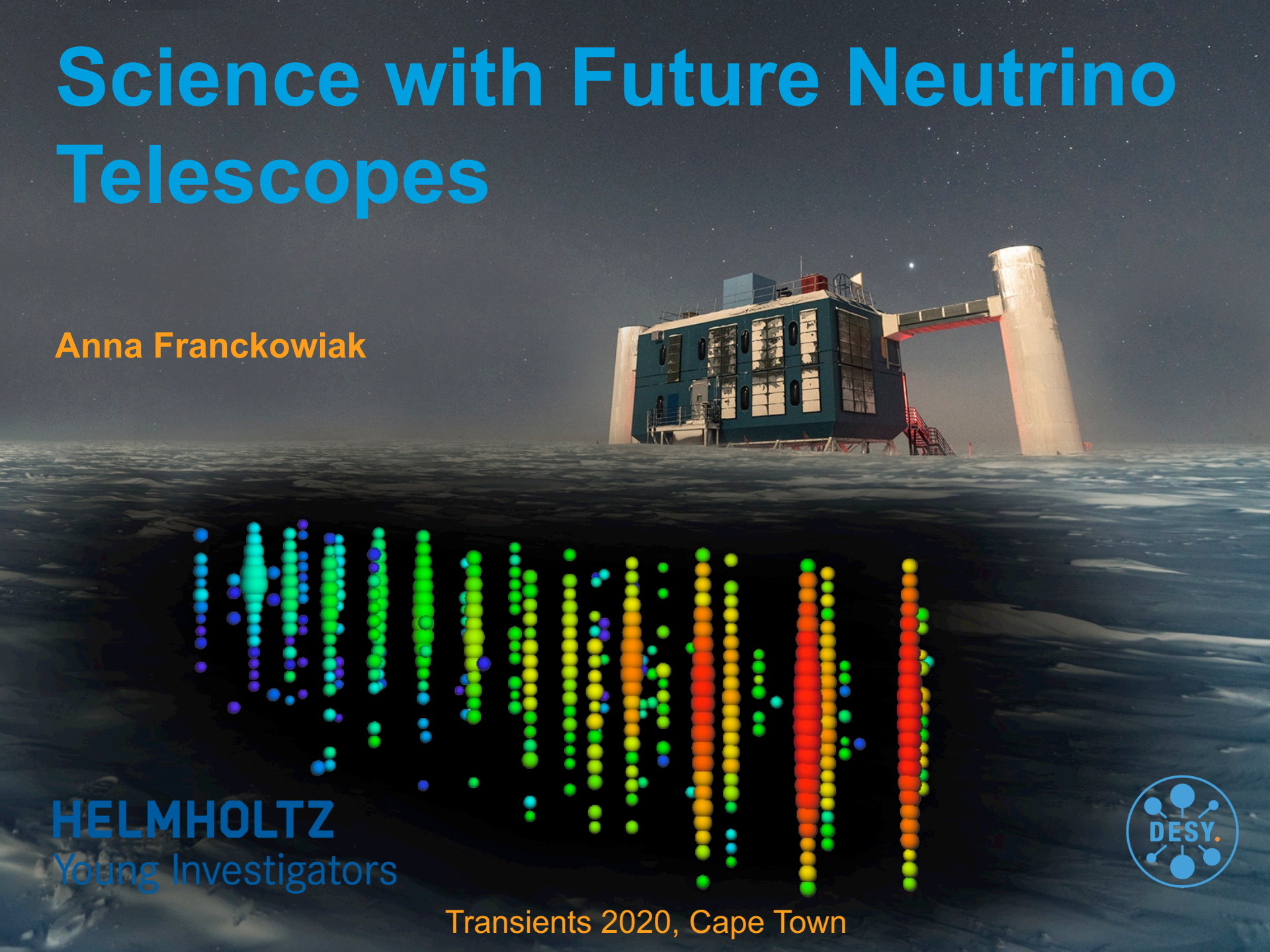
Science with Future Neutrino Telescopes

Anna Franckowiak



HELMHOLTZ
Young Investigators

DESY.

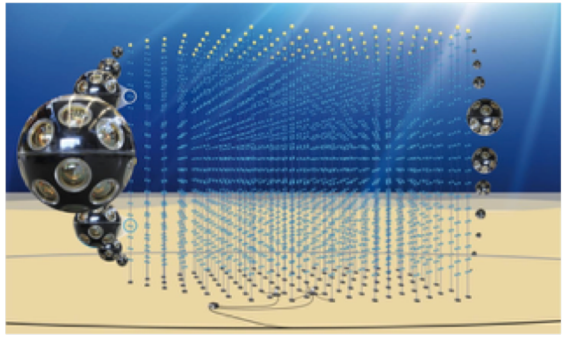
Transients 2020, Cape Town

Next Generation Neutrino Telescopes

Neutrino sources
on the southern sky

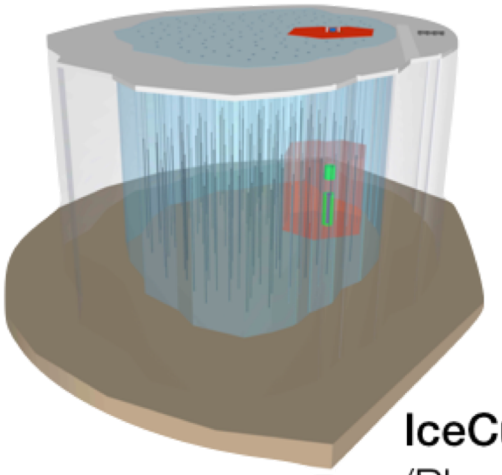
Today's neutrino telescopes

Neutrinos bei EeV
Energien

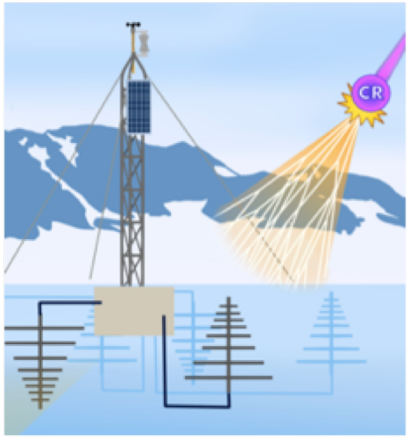


KM3NeT / Baikal-GVD
(construction started)

5x better sensitivity
in the TeV-PeV
energy range

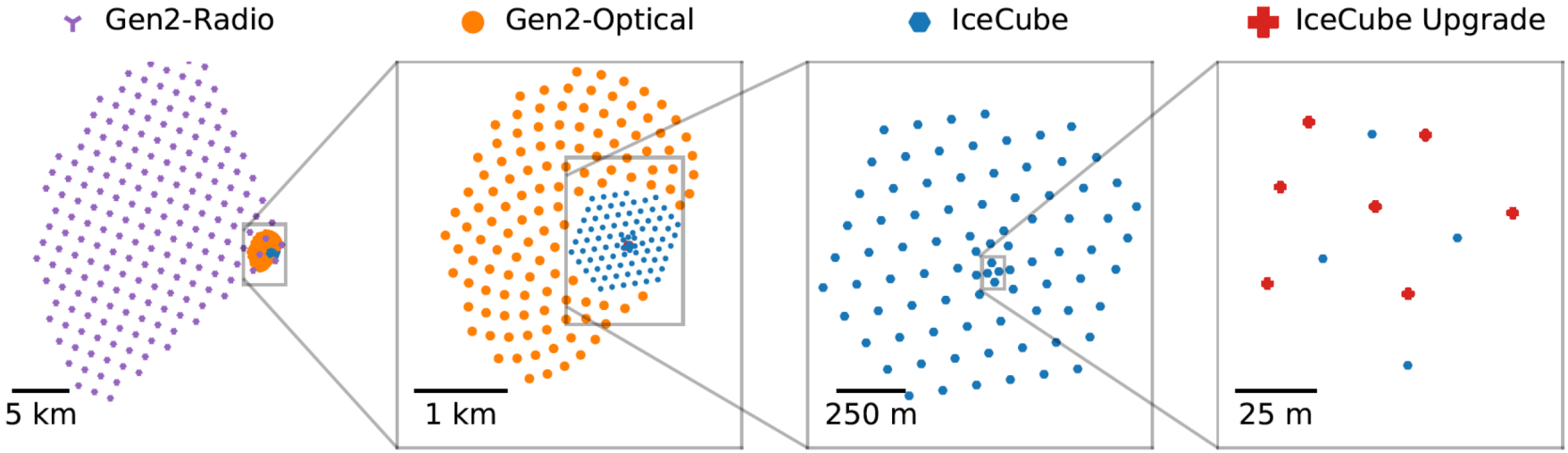


IceCube-Gen2
(Phase 1 started)



ARA/ARIANNA,
RNO, Gen2-Radio
(proposals in)

Next Generation at South Pole

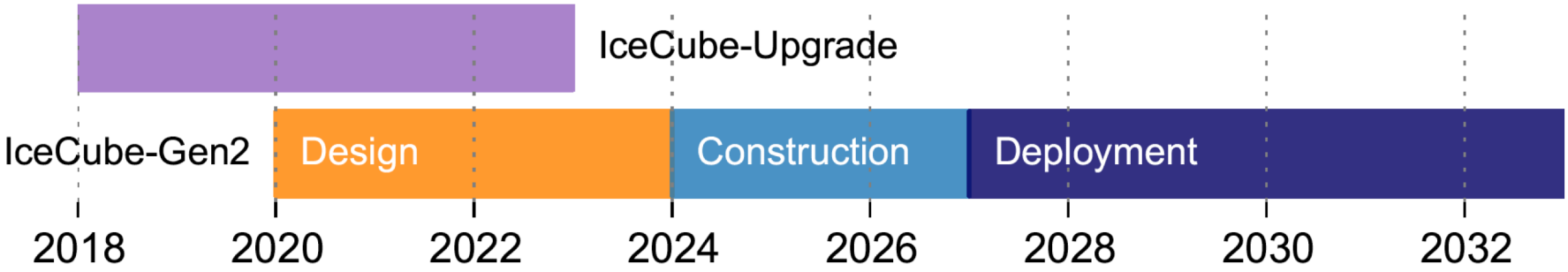


- 200 stations
- ~500 km^2
- E > 10PeV

- 120 strings
- 80 DOMs each
- 8 km^3
- E>10-30TeV

- 86 strings
- 60 DOMs each
- 1 km^3
- E>100GeV

- 7 strings
- ~100 DOMs each
- E>1GeV



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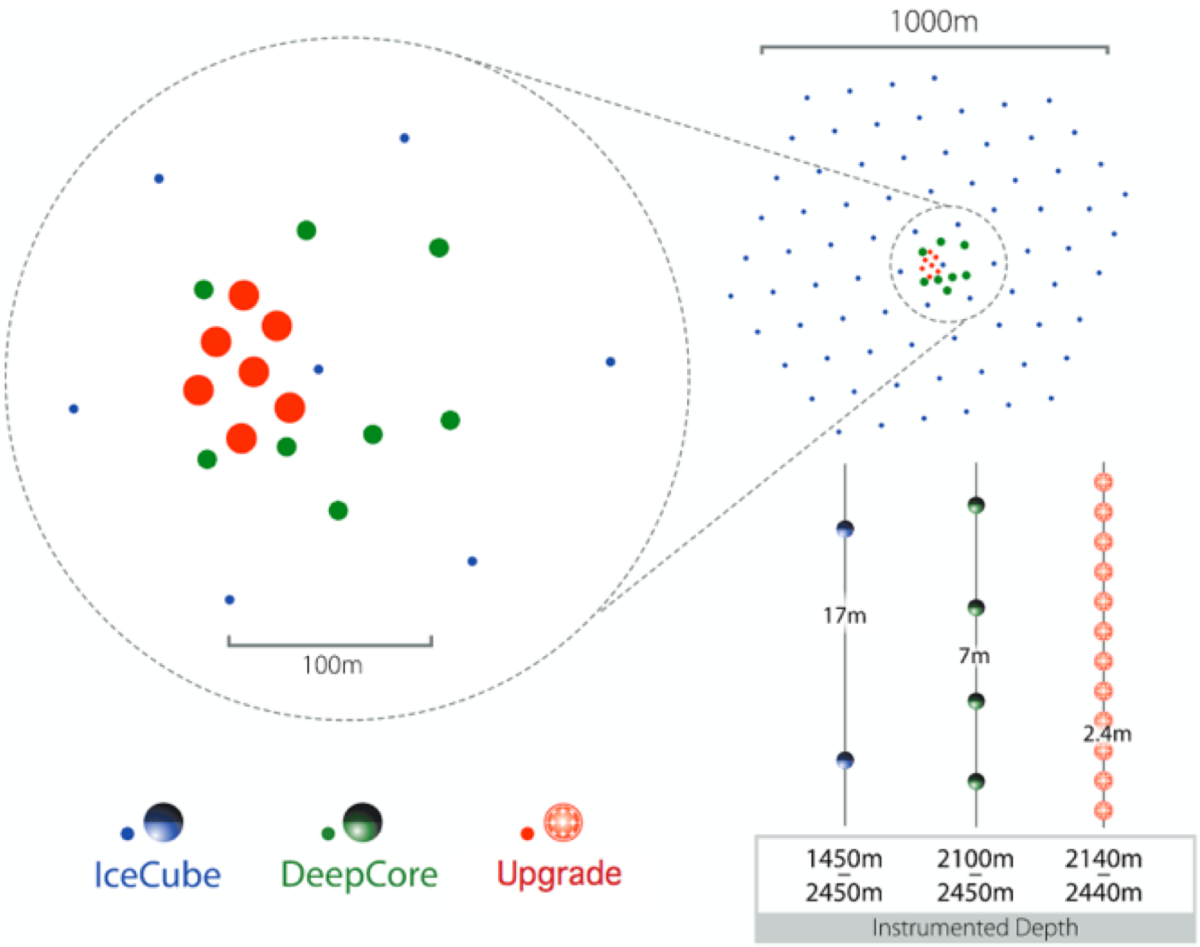
The IceCube Upgrade

- First step towards IceCube-Gen2
- 23 M$ NSF award + 15M$ external funding
- 7 new strings in the center of IceCube
- New calibration devices
- Science focus:
  Neutrino properties
  Optimized for GeV



Densely instruments and Improved Sensors

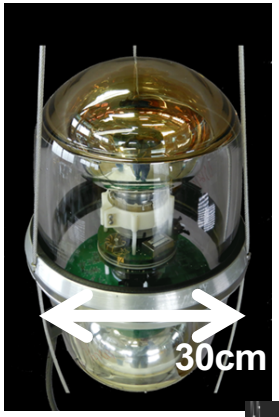
IceCube module

pDOM $10''PMT$

Upgrade modules

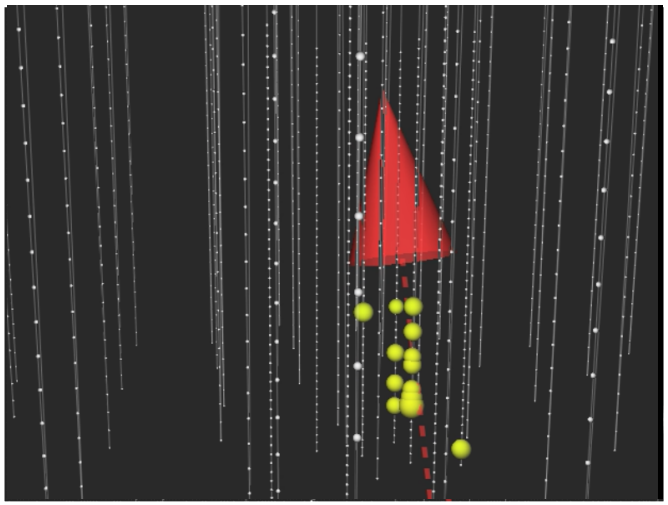
mDOM $24\times3''PMT$

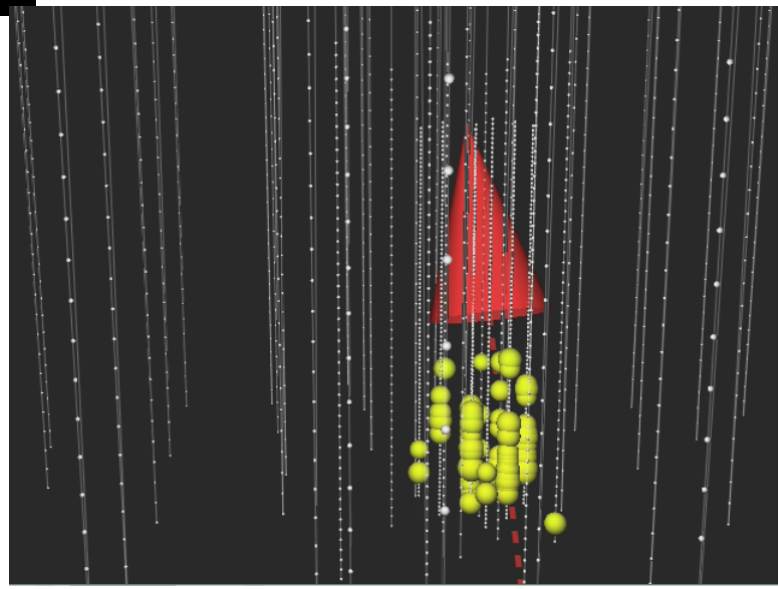
D-Egg $2\times8''PMT$



>10 times more effective photocathode area per volume compared to DeepCore
→ Better angular and energy reconstruction

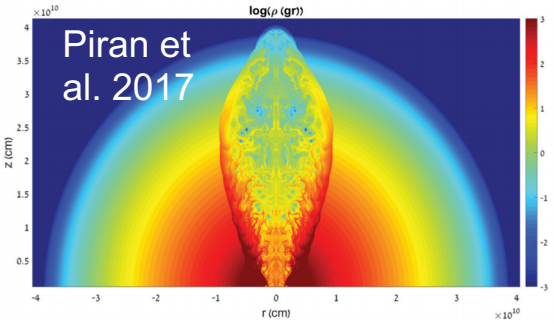
Upward-going 20 GeV tau neutrino

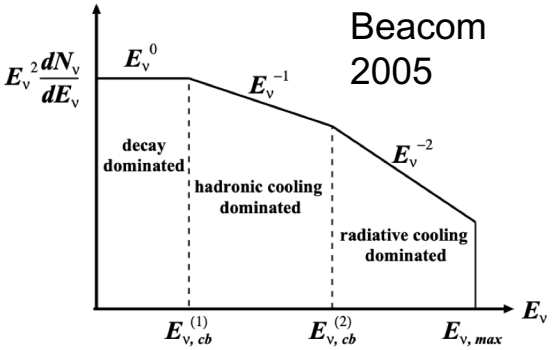




Science at low energies

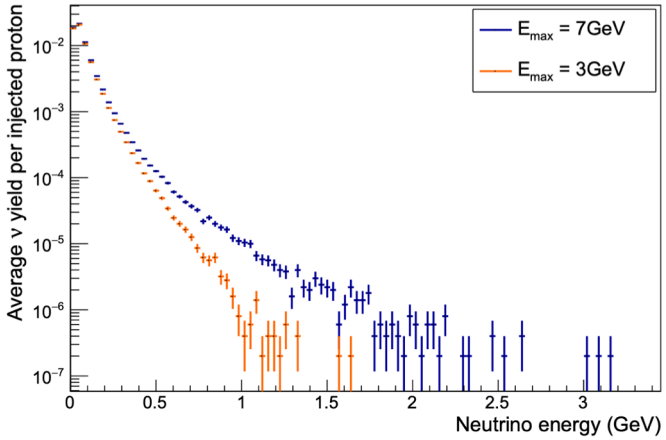
Choked jet supernovae might have soft spectrum





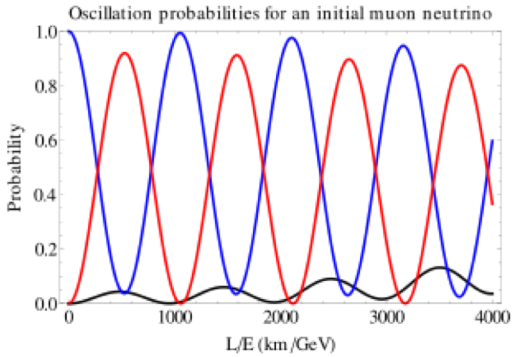
Ando & Beacom 2005

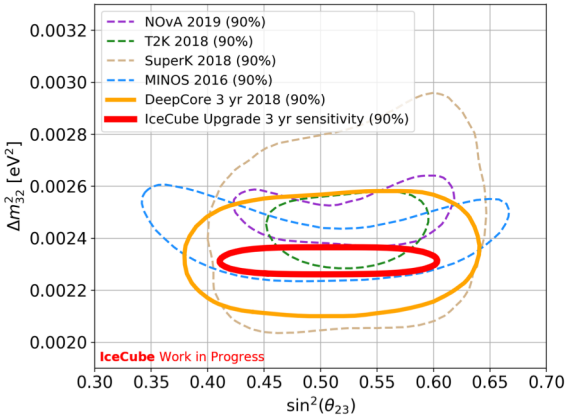
Neutrinos from solar flares



G. de Wasseige for the IceCube Collaboration, 2017

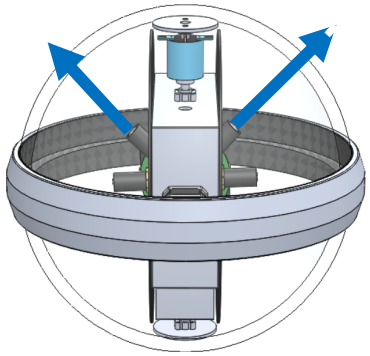
Neutrino properties





Upgrade Calibration

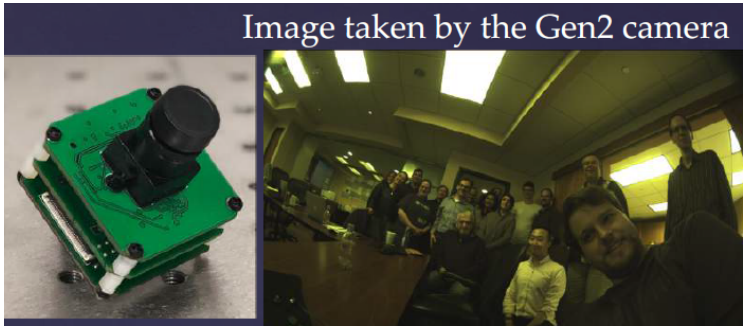
Pencil beam (beaming light source)

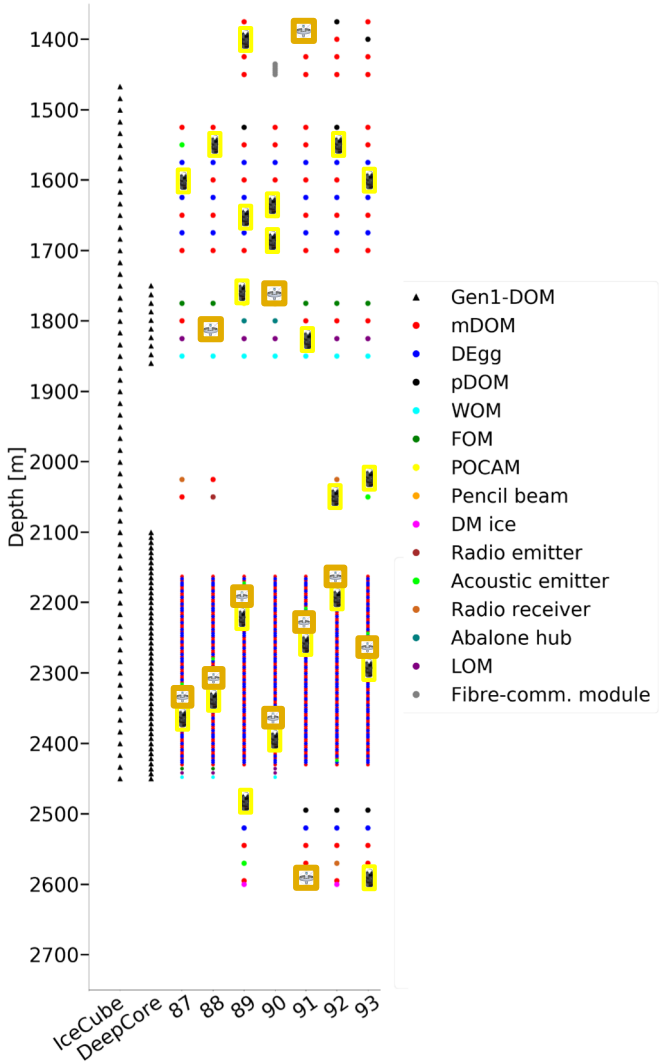


POCAM (isotropic light source)

LEDs in modules

Cameras in modules

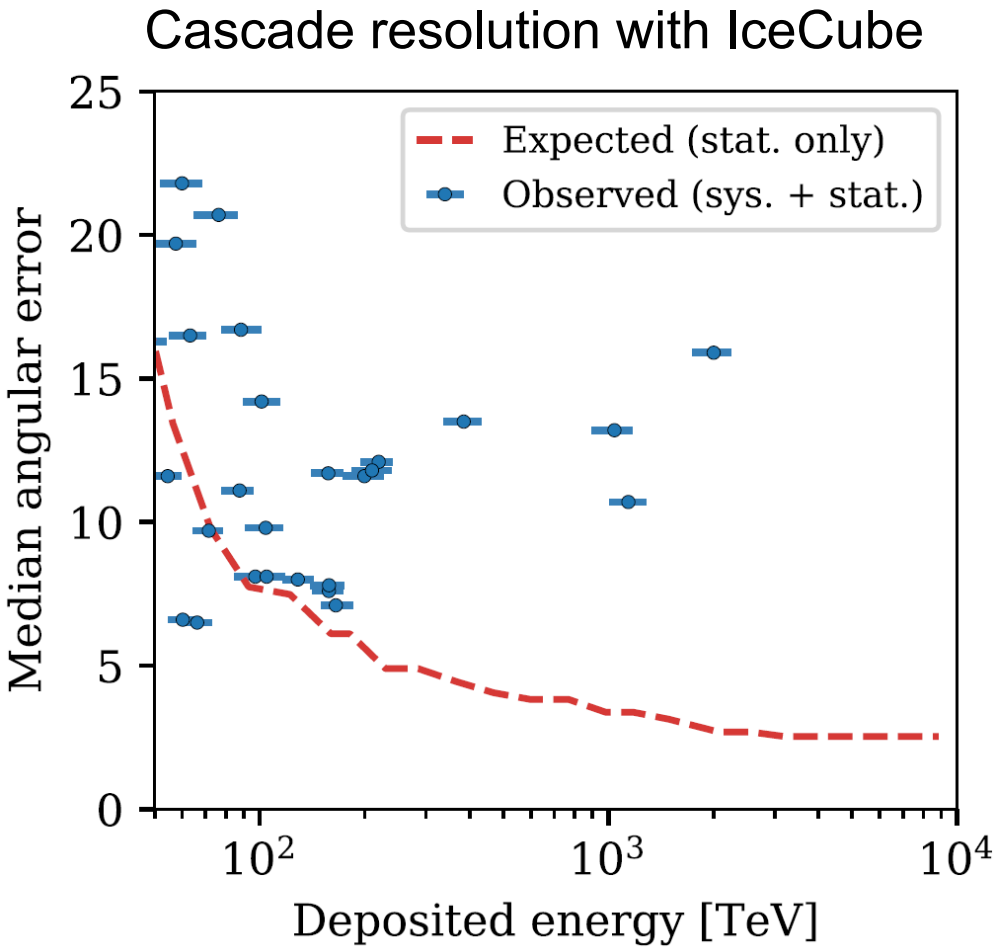




Improved calibration constants will be applied over 10 years of IceCube's archival sample

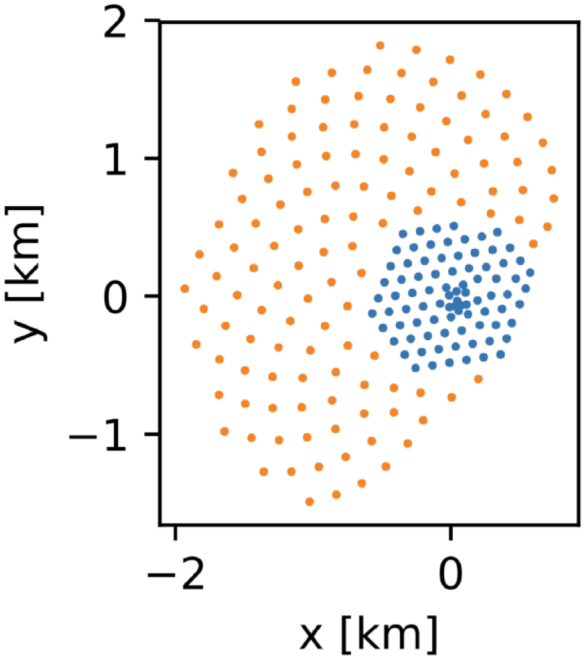
Calibration of IceCube Main Array

Calibration allows to create neutrino data sample with improved angular reconstruction



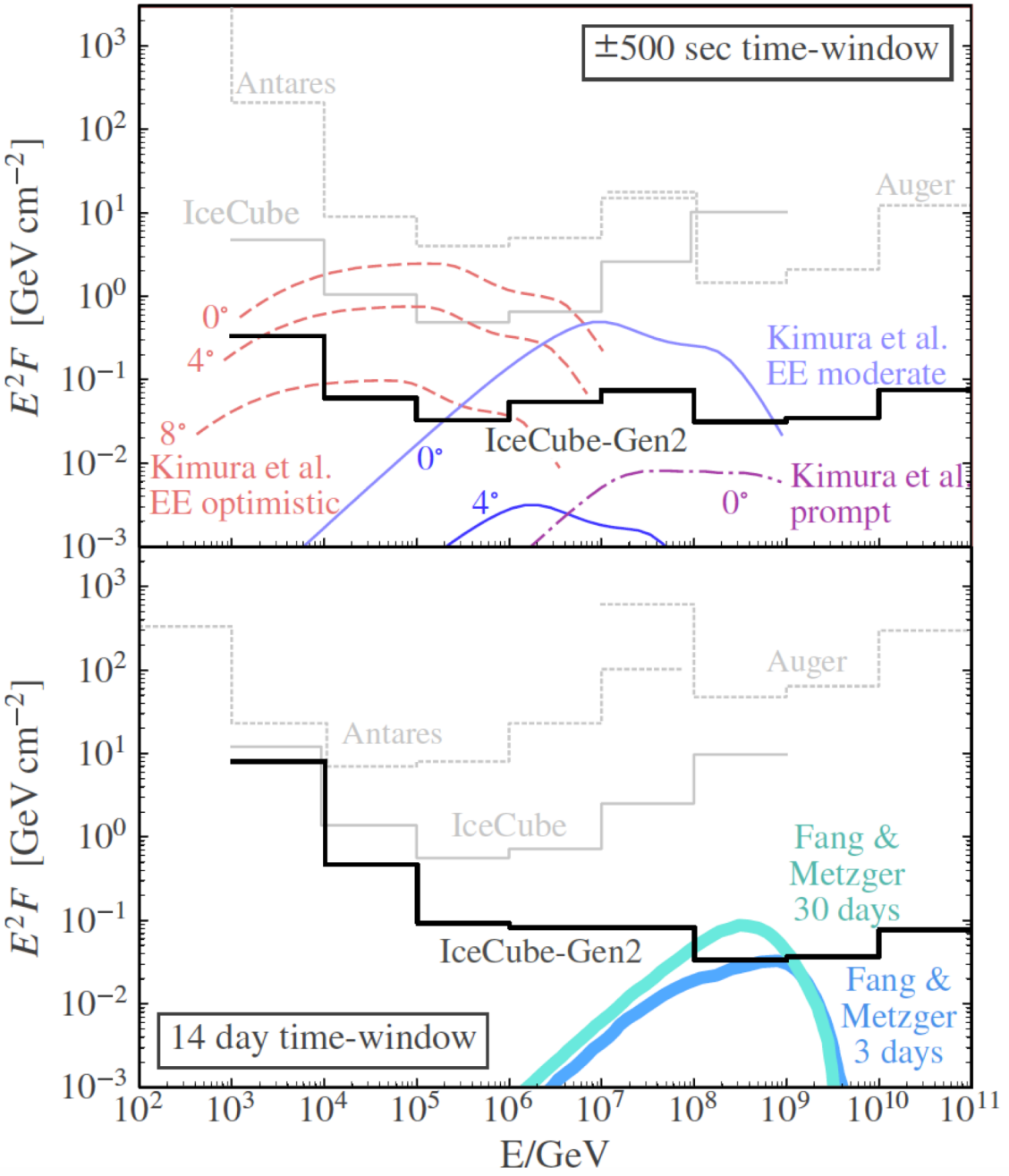
IceCube-Gen2 InIce Array

Sensitivity



8 times larger instrumented volume compared to IceCube

Gravitational wave follow-up with IceCube Gen2



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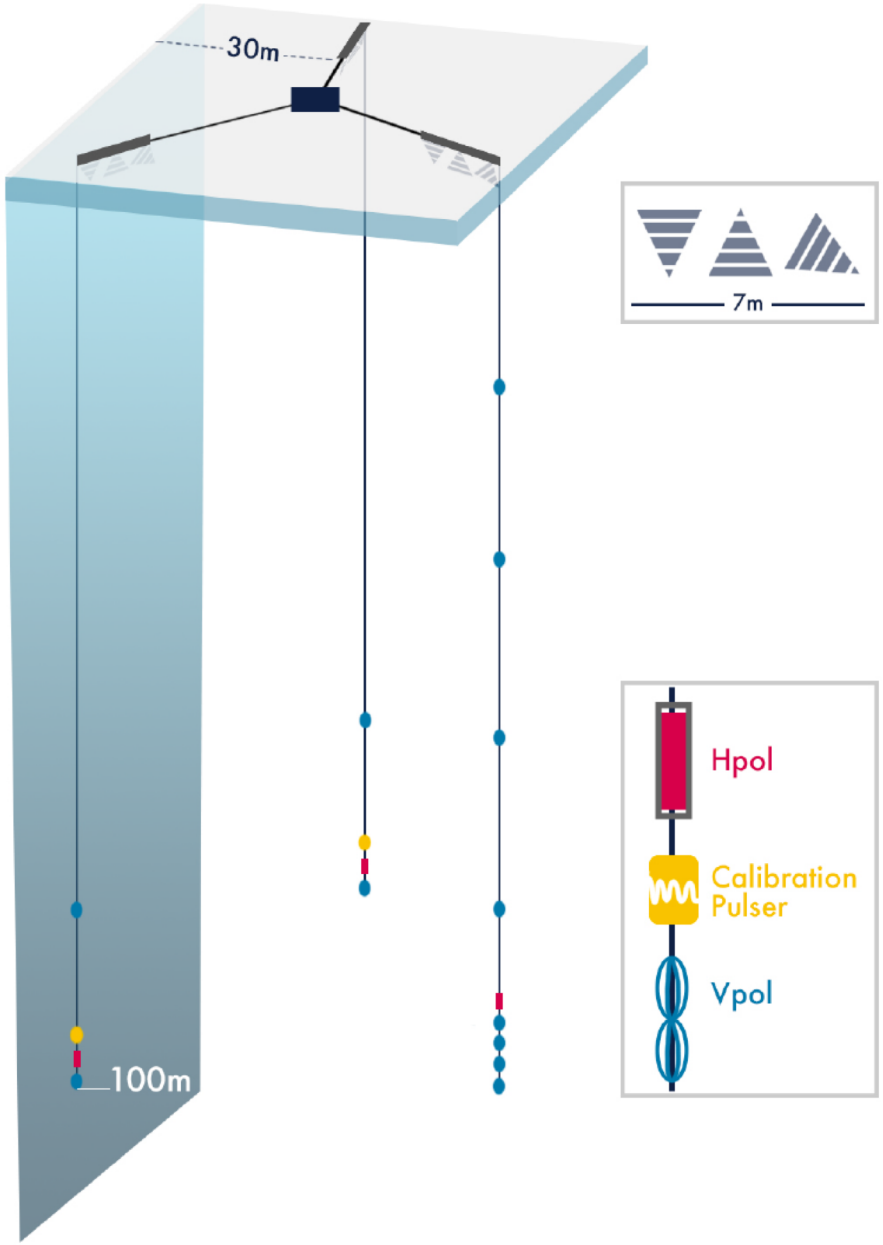
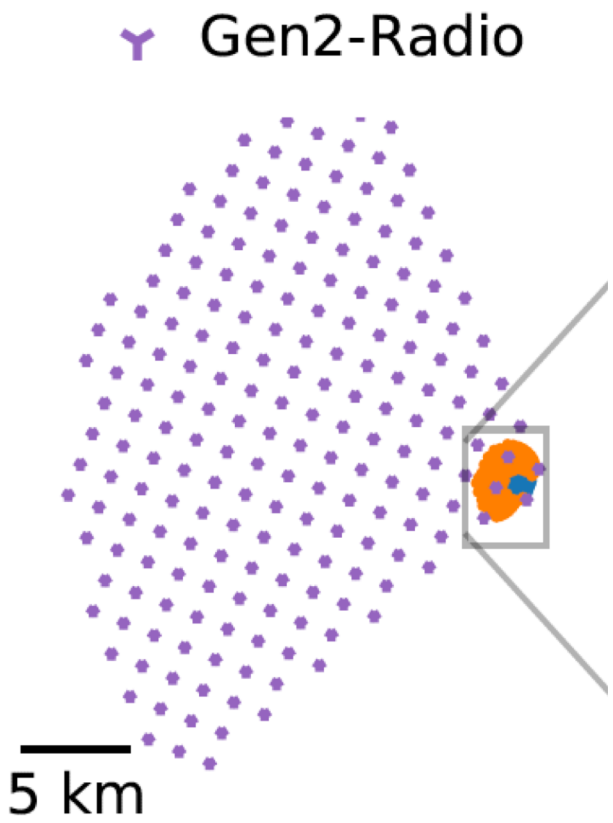
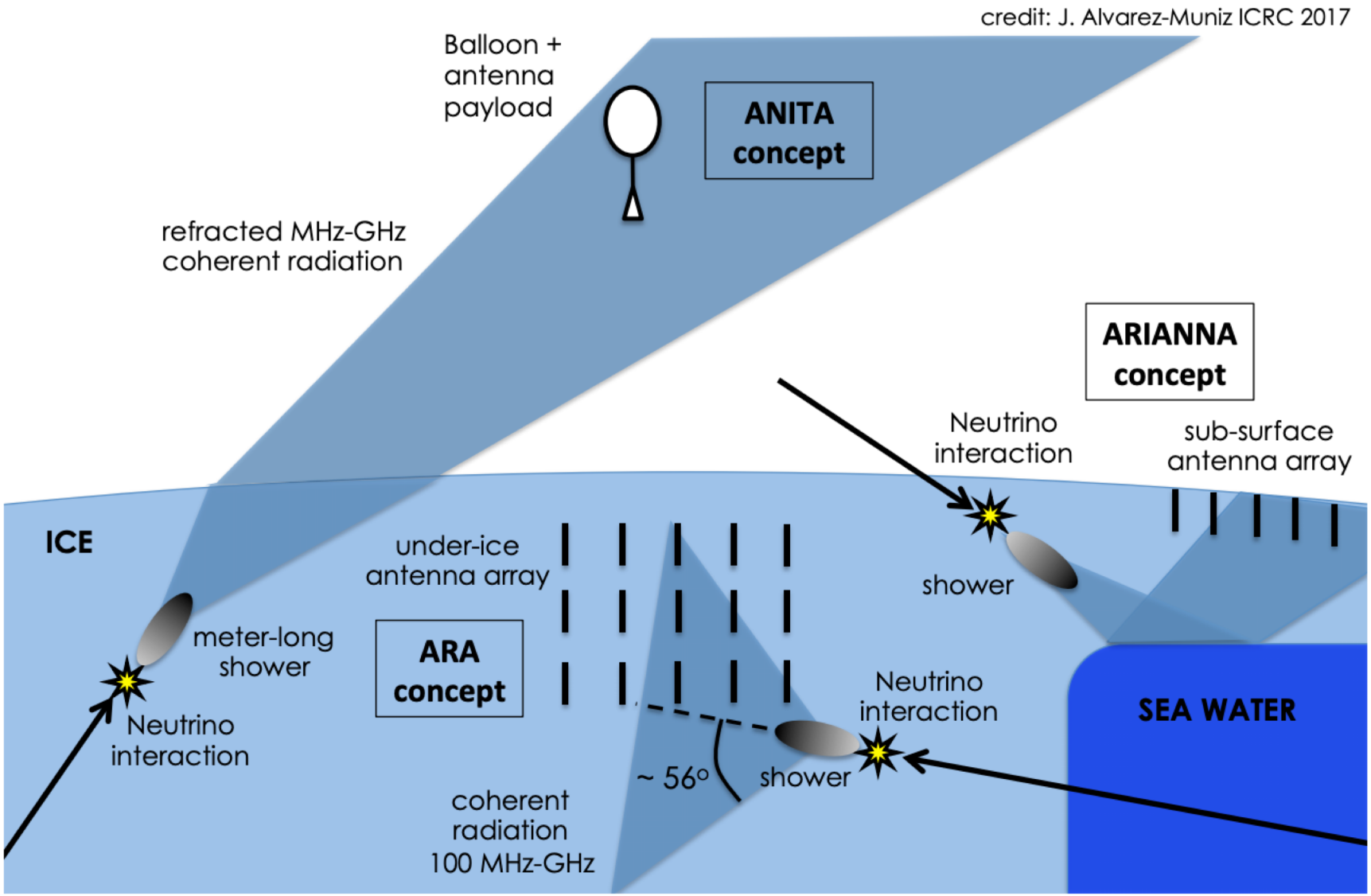

30m
7m
Hpol
Calibration Pulser
Vpol
100m

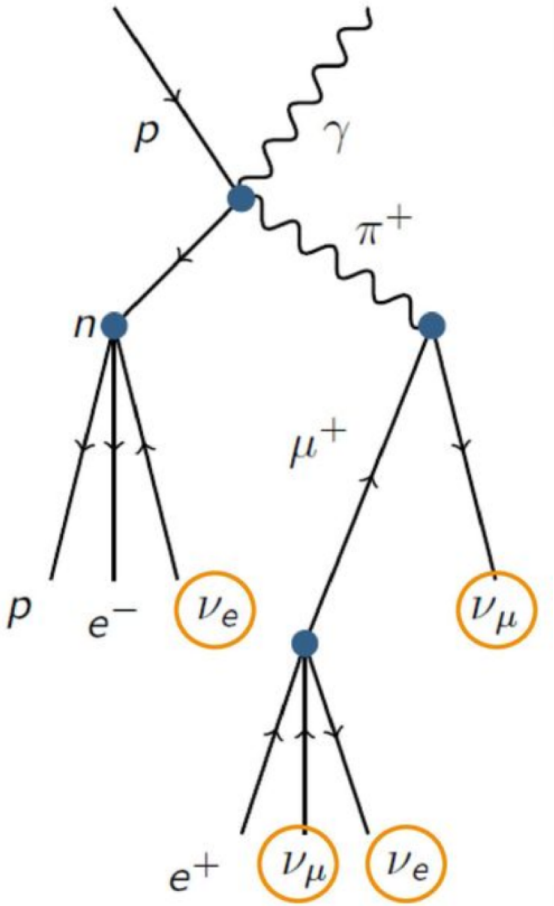

Gen2-Radio
5 km

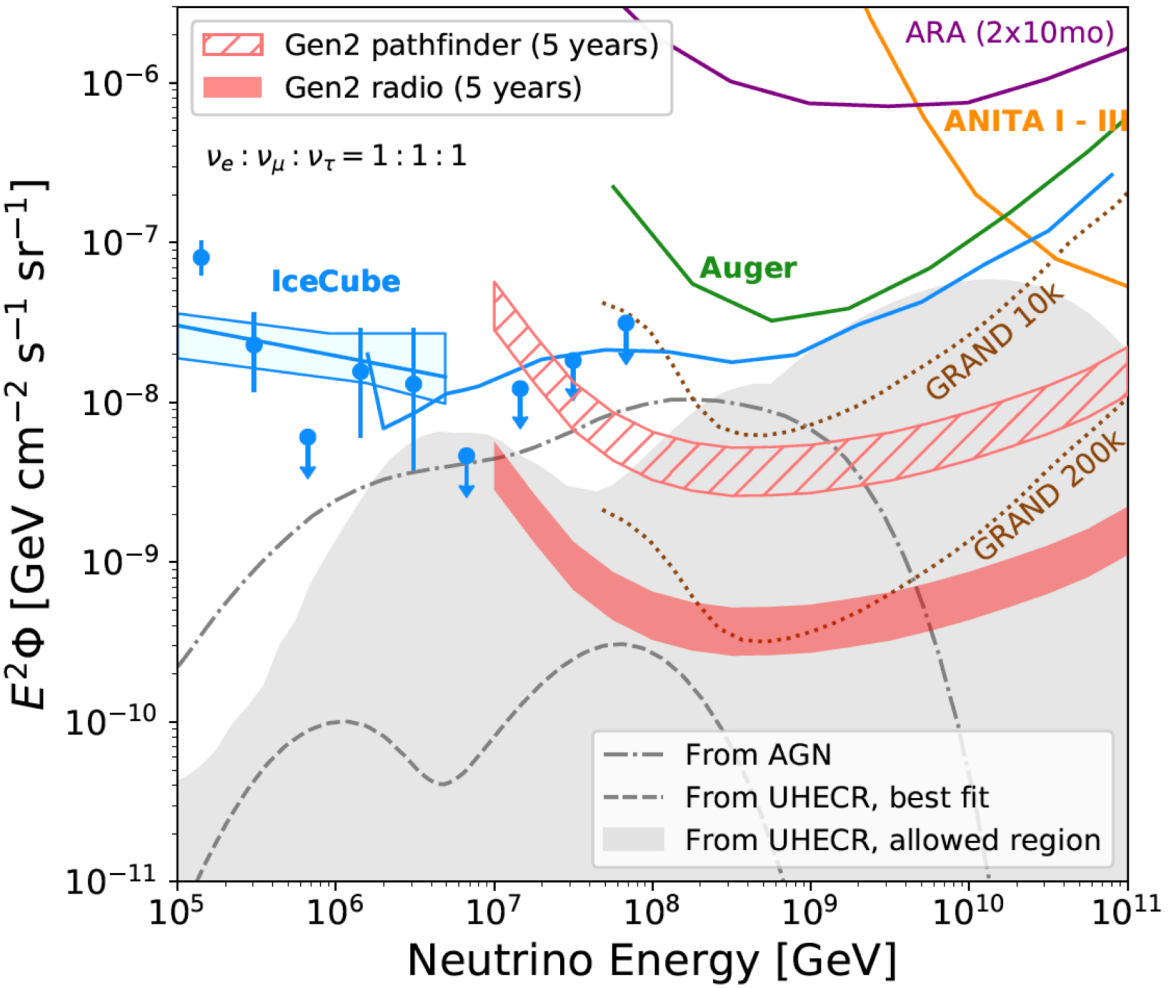
Radio Detection Concept



Radio: Cosmogenic

UHECR EBL Photon





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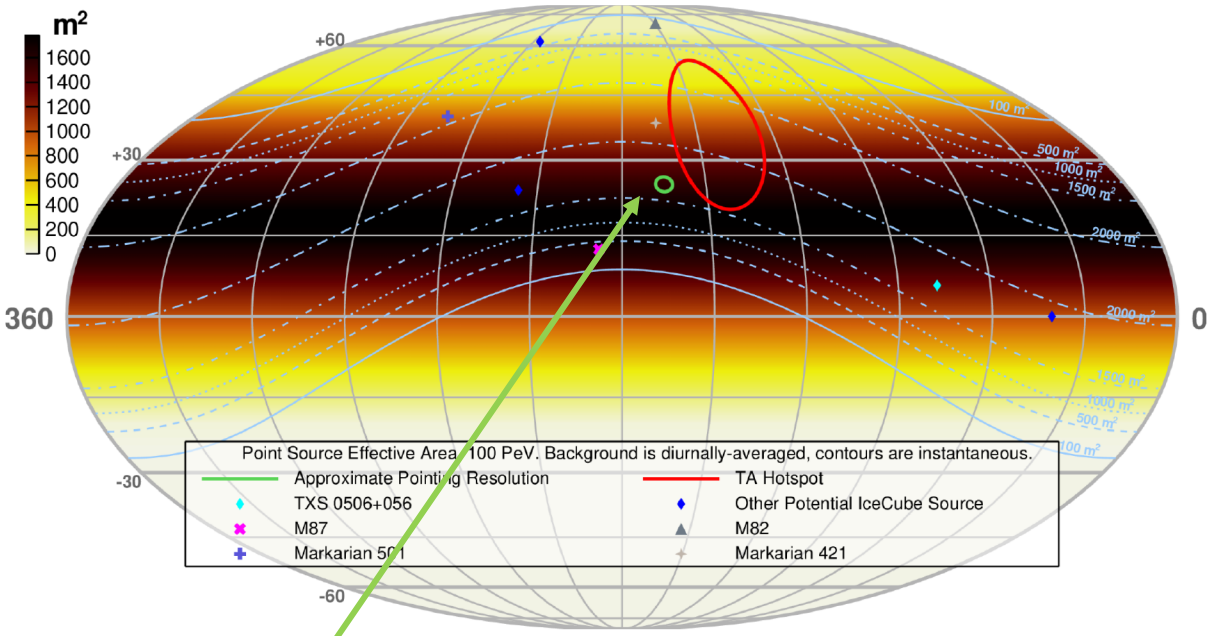
Radio: Astrophysical Neutrinos

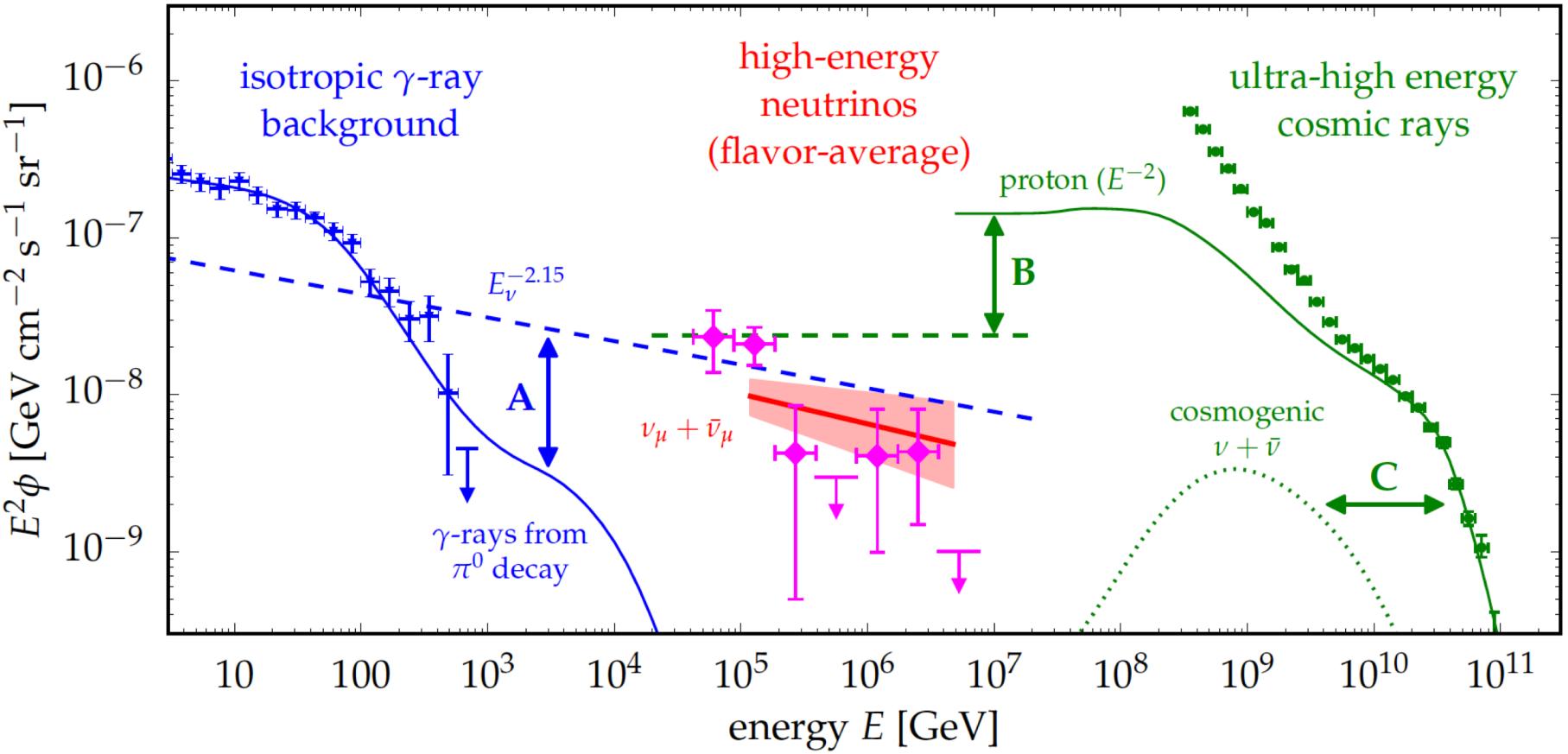
Point source effective area of path finder in Greenland at 100 PeV



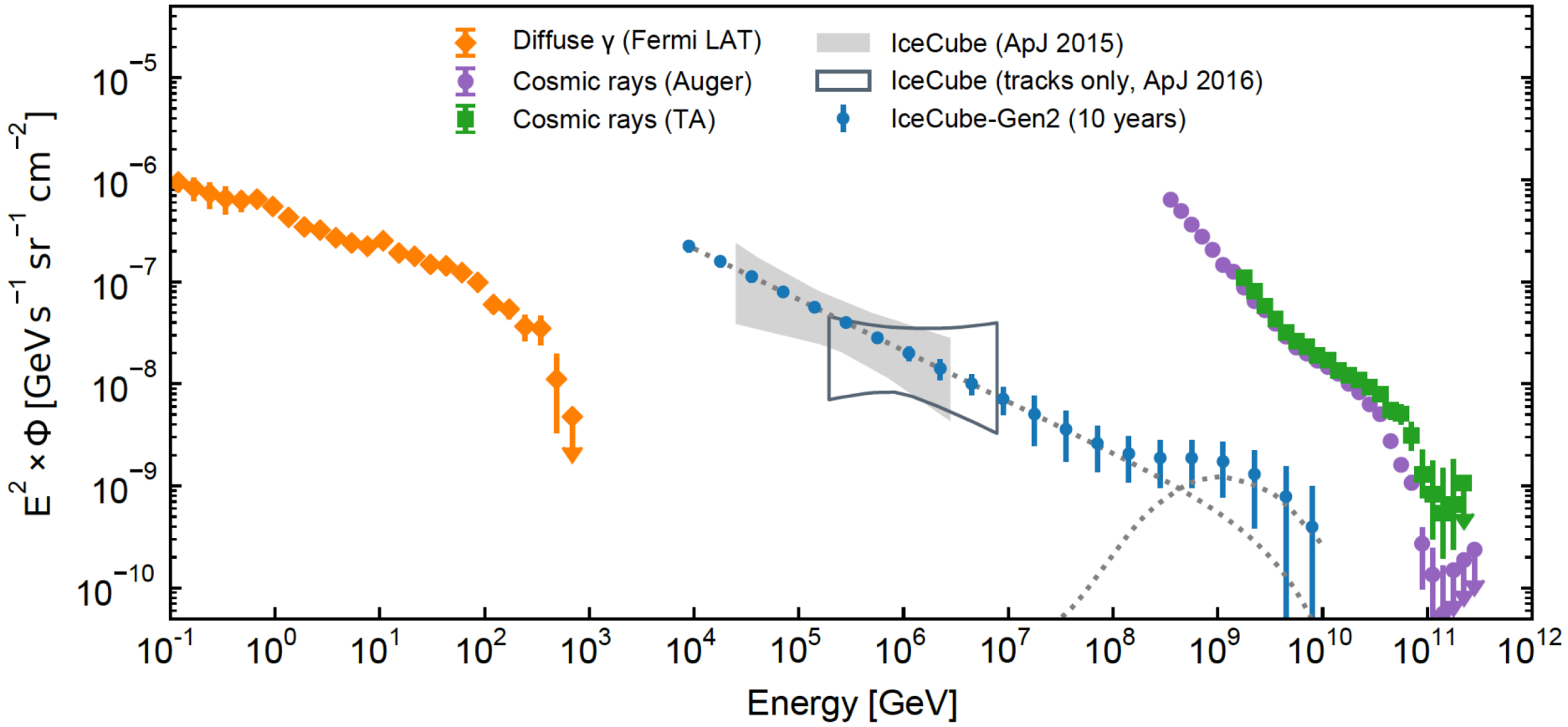
Typical 90% neutrino localization: 3.5deg in RA and 1.5deg in Dec

Slide provided by A. Nelles

Diffuse Spectrum with IceCube



Diffuse Spectrum with IceCube-Gen2



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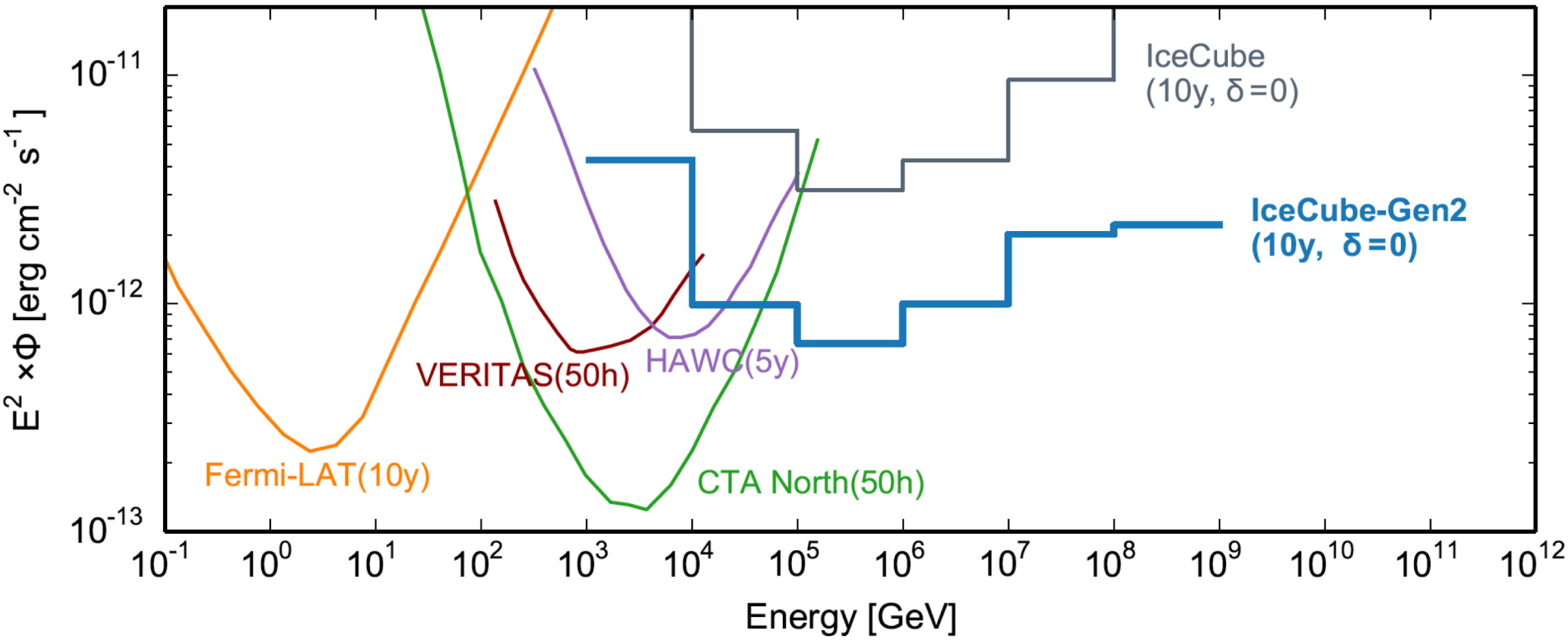
IceCube-Gen2: Performance in MM context



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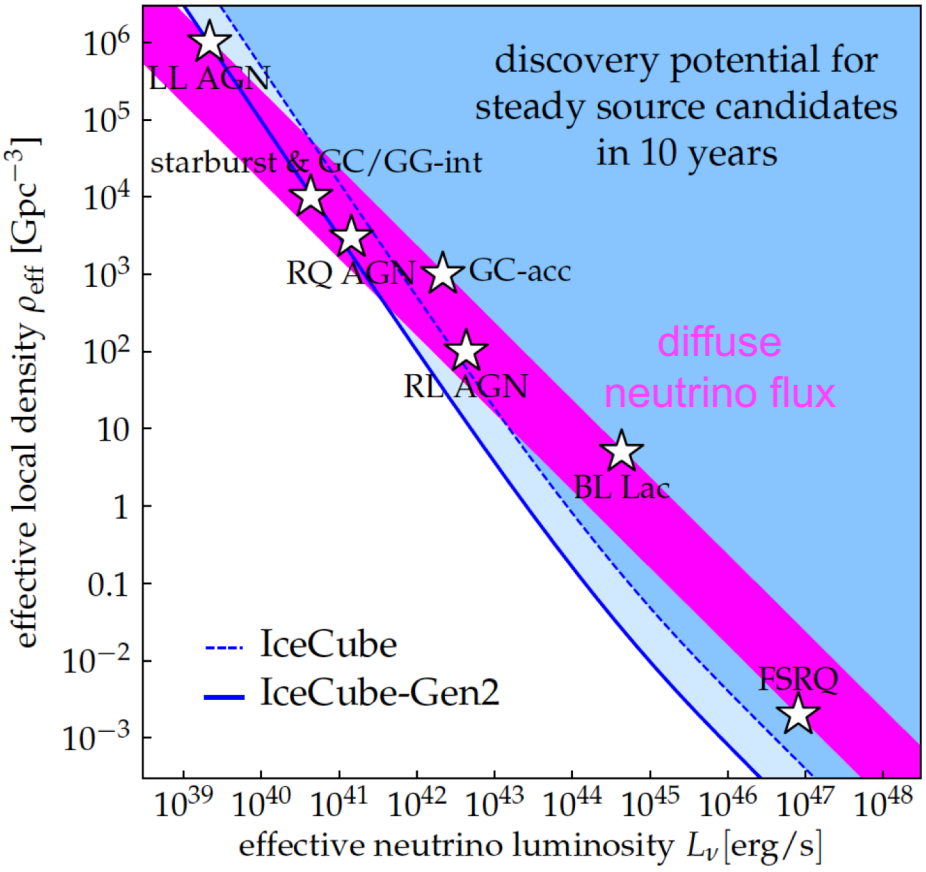
“Kowalski” Plot



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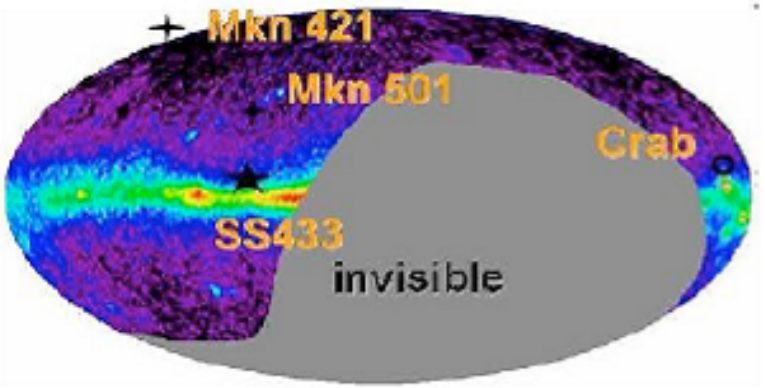
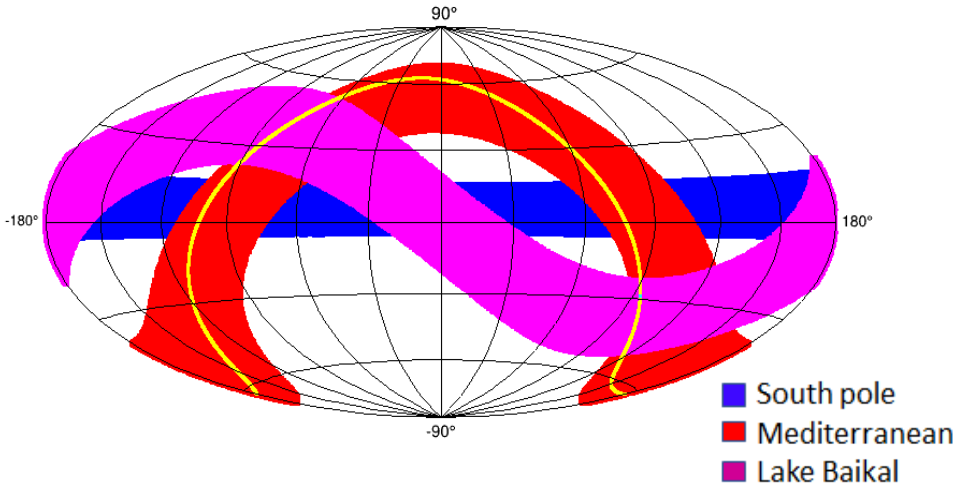
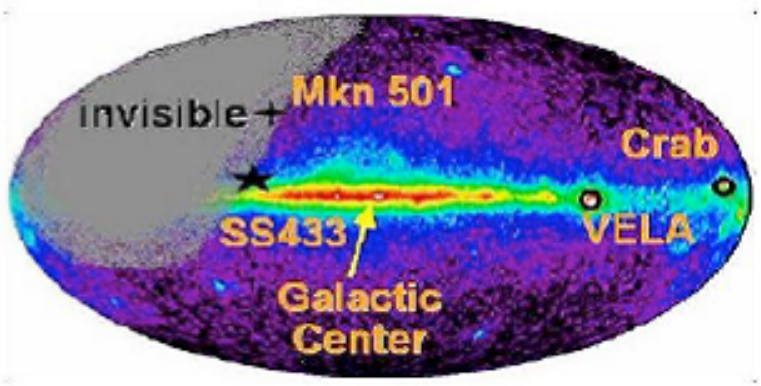
Next Generation in the Mediterranean

South Pole





Mediterranean Sea



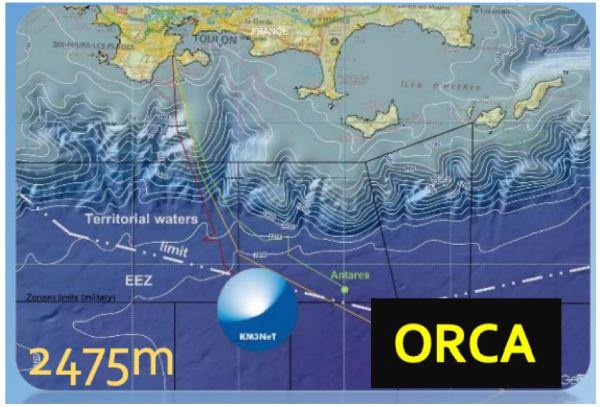
At highest energies : neutrinos don't make it through the Earth: horizontal tracks are golden channel

KM3NeT: ARCA & ORCA

- ORCA: French coast
  - Science focus on low-energy neutrinos
- ARCA: close to Sicily
  - Science focus on high-energy neutrinos

	ARCA	ORCA
Location	Italy	France
DU distance	90 m	23 m
DOM spacing	36 m	9 m
Instrumented mass	2*500 Mton	8 Mton

Completion planned by end of 2024



Completion planned by end of 2023, second block end of 2026

KM3NeT: New Sensor Technology

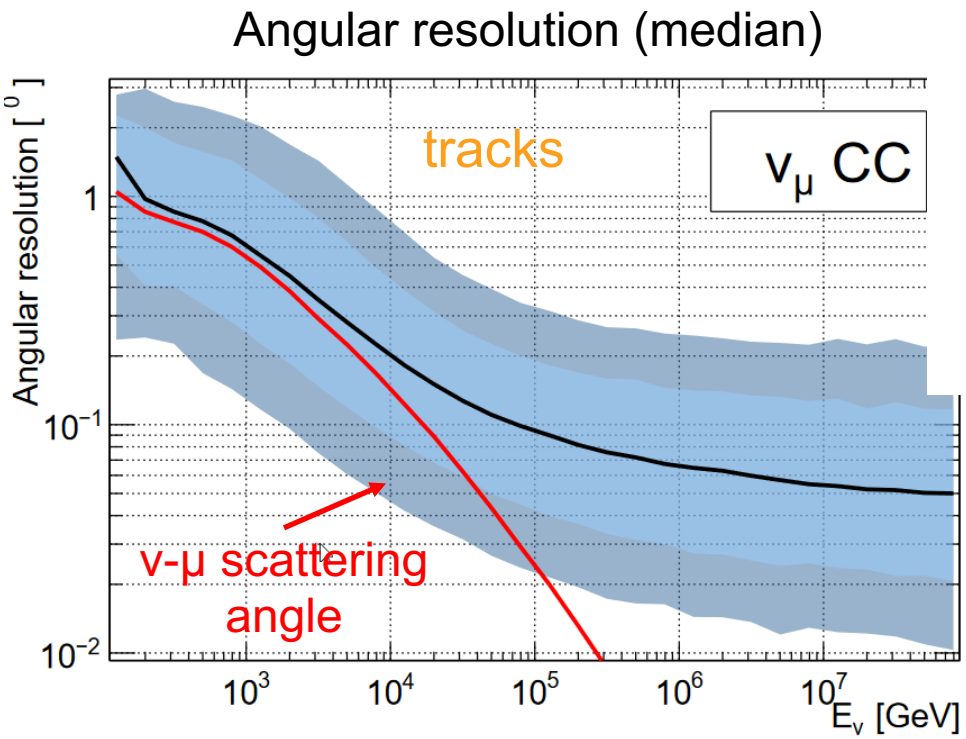
Multi-PMT design

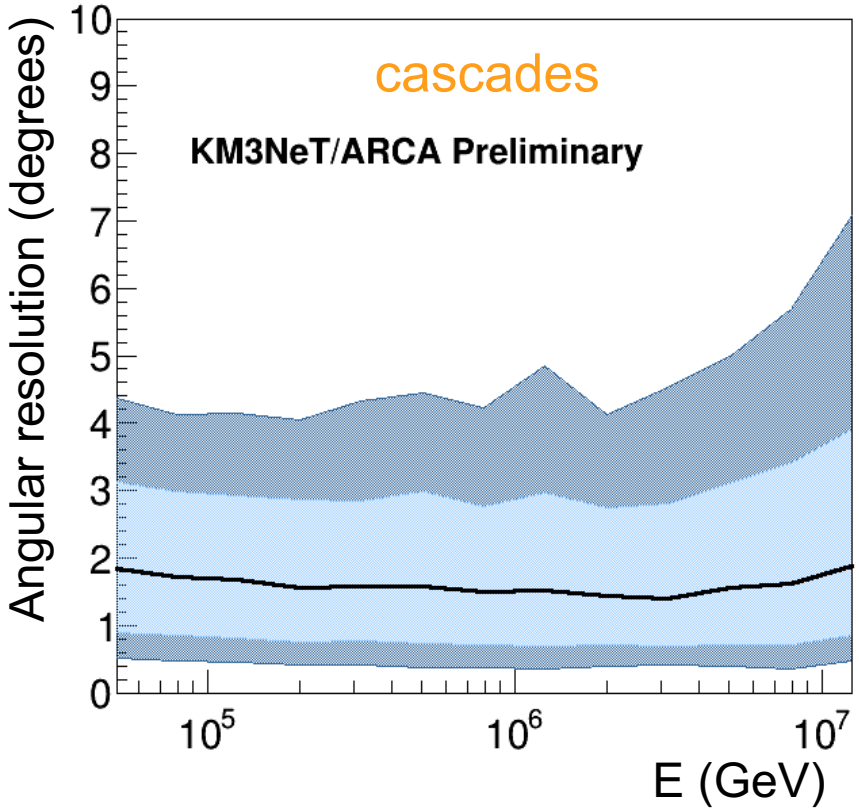
- Cost effective : 3x area of 10” PMT
- Photon counting
- Directional sensitivity

ANTARES structure
With ~same sensor area

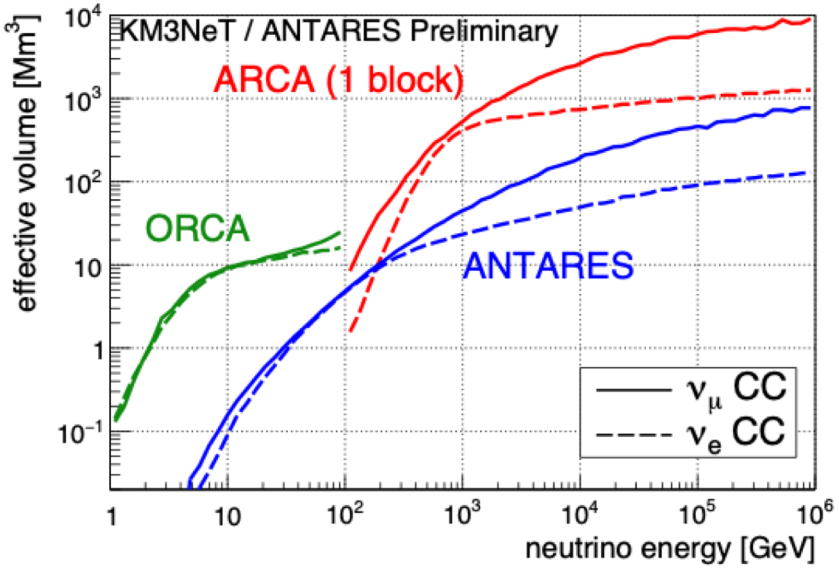
ARCA Angular Resolution

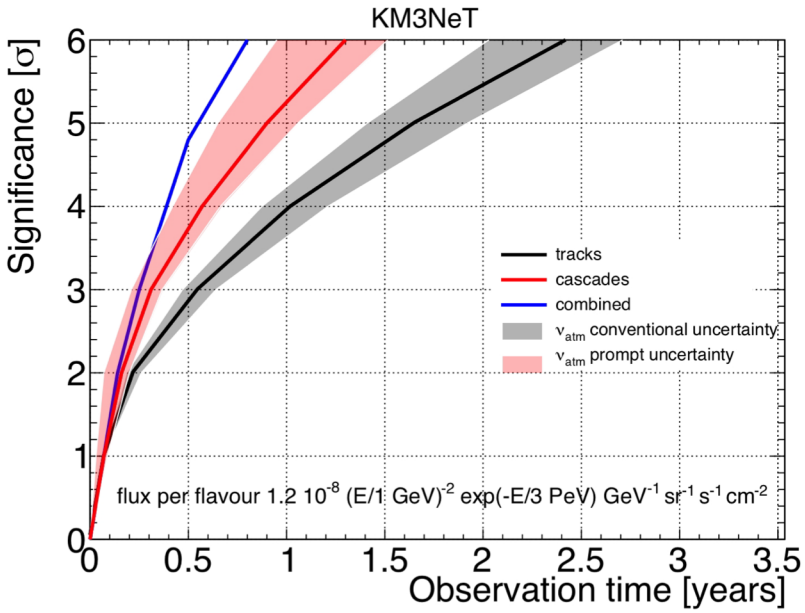
- Excellent resolution due to good water properties
- Physics limited < 10 TeV
- 0.1 degree at 100 TeV
- 0.05 degree at 100 PeV





Confirming cosmic neutrino flux





Can confirm IceCube flux within a year of data

TXS 0506+056 with KM3NeT-ARCA

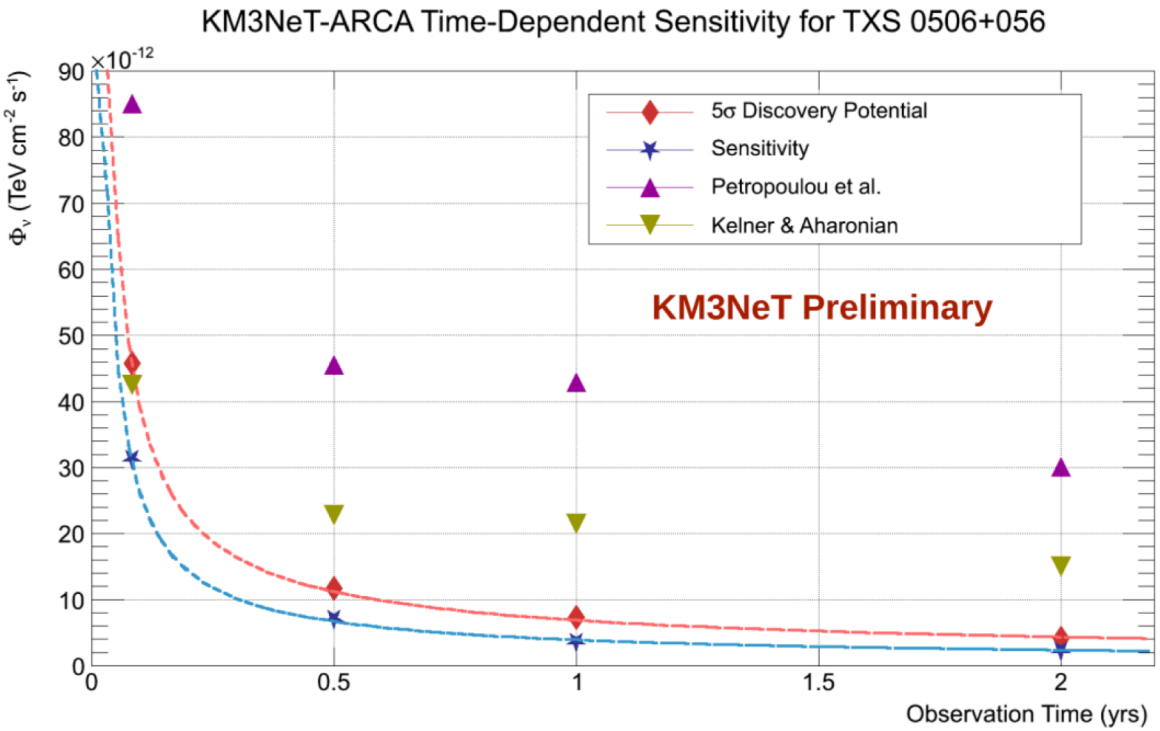
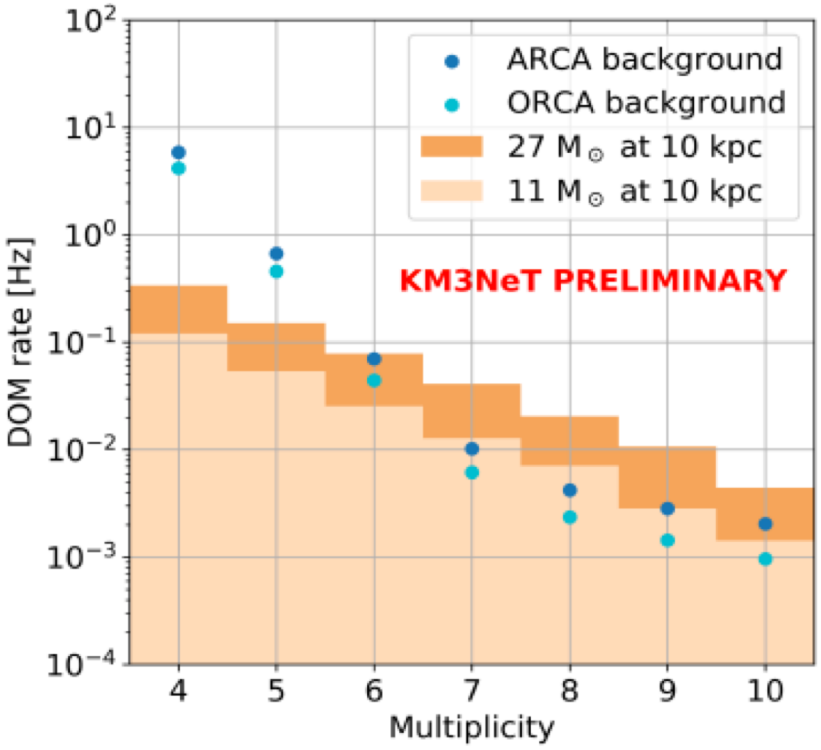
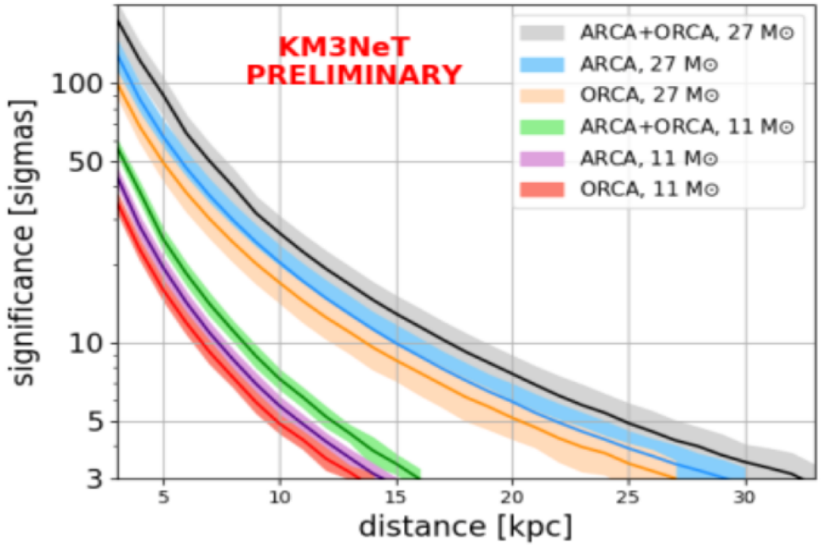


Figure 4: The 90% C.L. sensitivity and 5σ discovery potential with 50% probability for 2 blocks of KM3NeT-ARCA to the blazar TXS 0506+056, shown with the expected neutrino fluxes from TXS 0506+056 during its gamma-ray flare, derived with the Petropoulou and the Kelner models

Supernova Detection

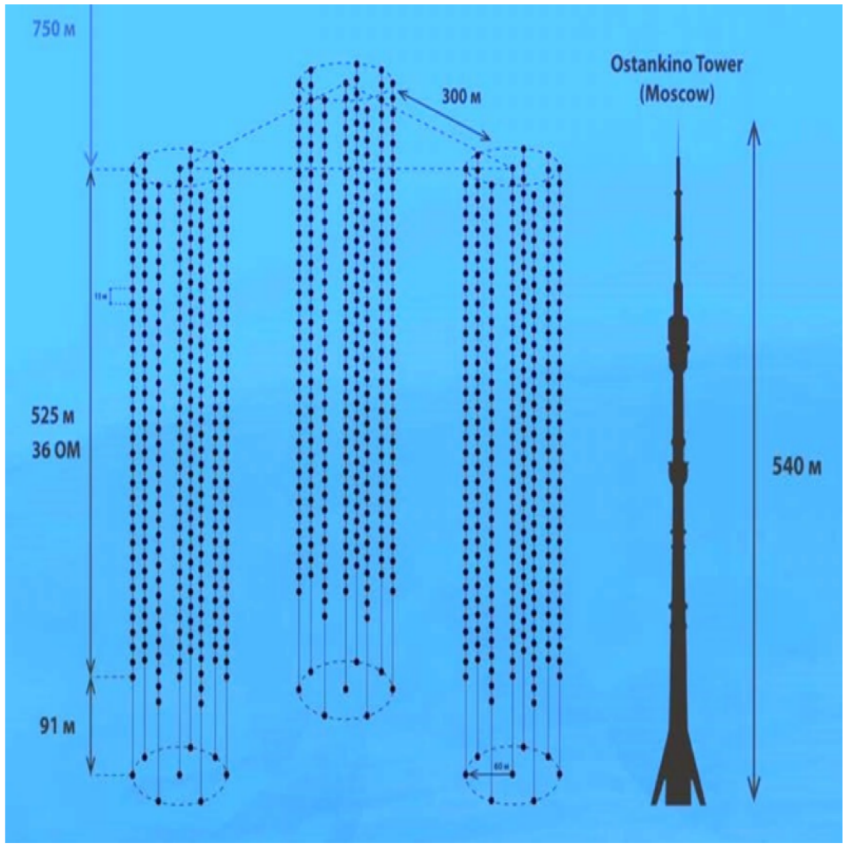


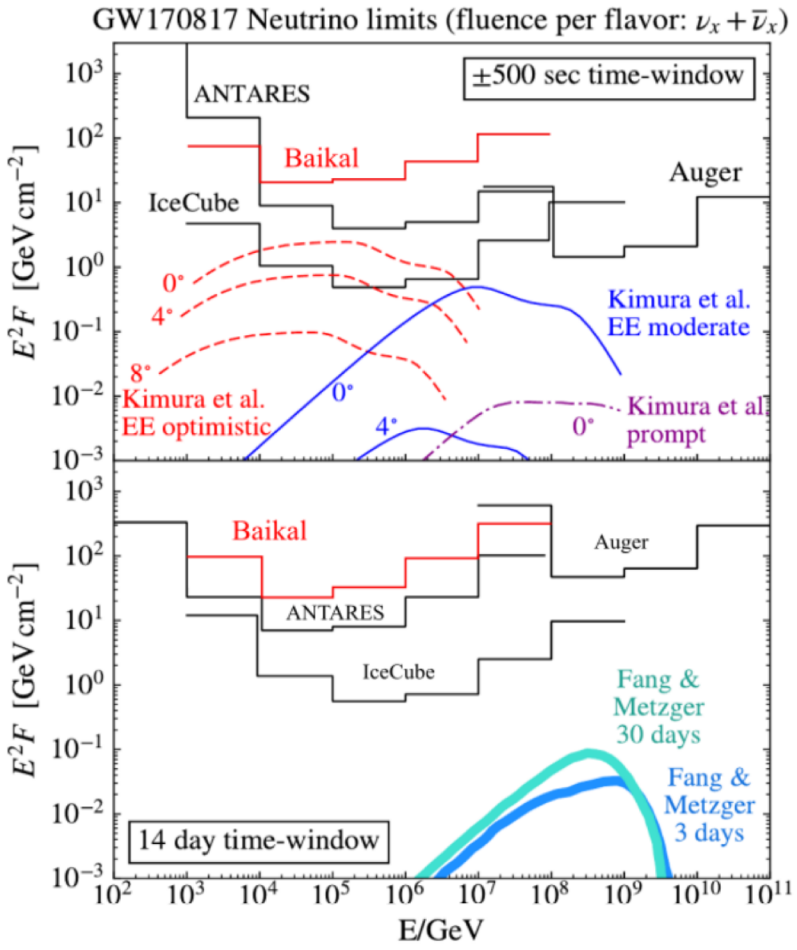


Supernova neutrino detection previously not possible in Mediterranean due to large background

combined sensitivity: 5σ for ARCA+ORCA for 27$M_\odot$ at a distance 25kpc

Next Generation at Lake Baikal: GVD





Currently 0.25 km^3, 0.4 km^3 expected by 2021.

Baikal-GVD collaboration, arXiv: 1808.10353

Summary

- New bigger and better neutrino detectors in the Mediterranean, Lake Baikal and the South Pole → improved angular and energy resolution, sensitivity and sky coverage, broader energy coverage
- Rich science program
  - MeV Supernova neutrinos
  - GeV neutrinos from solar flares or choked-jet supernovae
  - TeV neutrinos from e.g. blazars
  - Cosmogenic neutrinos at >10 PeV through radio detection